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# COMMUTER Model Coefficients

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# COMMUTER Model Coefficients

The travel impacts calculated in the COMMUTER Model are based on logit mode-choice coefficients. The COMMUTER Model impacts are highly sensitive to the values of these coefficients, which are used to predict mode share changes in response to changes in travel time and cost associated with transportation control programs. Given this high degree of sensitivity, it is important that COMMUTER Model users understand the basis for these coefficients and how they are validated and used in transportation modeling. Potential users of the model should evaluate the influence of the coefficients, perform sensitivity tests to understand their impacts, and verify that there is consistency among the coefficient values used in related transportation planning models and the coefficient values used in this model for the city or local area being analyzed. The purpose of this discussion is to educate users about these issues. This discussion covers the following elements relating to the use of mode-choice coefficients in the COMMUTER Model:

- **Modeling Techniques** outlines the various modeling processes that use coefficients of this type and identifies how the coefficients are used in the various models.

- **Review of the Coefficient Values** identifies the coefficients used in the COMMUTER Model and defines the range of values, averages, and categories that are used in the model.

- **Documentation of Sources** lists the specific documentation of the coefficient sources.

## Overview

The COMMUTER Model employs a simplified logit modeling process (called pivot point) that relies on locally derived coefficients to evaluate the influence of alternative measures on travel behavior. The coefficients are derived from observed travel behavior using standard survey techniques, statistical analysis, and modeling methods. Coefficients that have not been derived from observed travel behavior (such as composite measures or transferred coefficients) are not included as they could bias the average values. The fact that the coefficients are all derived using similar statistical methods explains why the coefficients are reasonably similar across the country. A review of the coefficients indicates that while they are relatively consistent across the country, there is enough variation in values between cities that it is essential that users understand the use of these coefficients. This report provides the user with this background information.

The mode-choice coefficients employed in the COMMUTER Model have been "validated" and are widely used in urban transportation modeling for a number of reasons, which include the following:

- The coefficients are derived from observed travel behavior using standard survey techniques, statistical analysis, and modeling methods.
- These coefficients are not estimated separately but rather as functions of the mode split behavior and are related to all variables included in mode-choice model equations.
- The coefficients are reasonably consistent across the country.
- Many metropolitan regions have used these coefficients to "backcast" known mode share conditions, e.g., to test the accuracy of their forecasting models.
- Metropolitan areas also have used these coefficients to verify before and after conditions of new transit services.

## Modeling Techniques

Coefficient values are used in all types of modeling techniques and represent similar behavioral aspects of travel in each case. The primary difference in the modeling techniques is that standard logit models estimate probabilities that a person would choose a certain mode (e.g., driving alone, carpooling, transit, etc.) based on all variables that impact travel decisions. Conversely, pivot-point models estimate these probabilities based only on the changes in specific variables. Both the TDM Evaluation Model and the COMMUTER Model are based on a pivot-point technique.

The pivot-point logit technique is a simplified version of the logit modeling process found in most mode-choice models, which are developed at the metropolitan level by Metropolitan Planning Organizations (MPOs). The primary difference between the standard logit modeling process and the pivot-point technique is as follows:

- Standard logit mode-choice models, as applied in regional travel models, include many different parameters, such as transportation level of service (e.g., travel times, transit fares, parking costs); area characteristics (e.g., employment density); and socioeconomic and demographic characteristics (e.g., income, household type). In order to apply the models, *baseline levels* and *changes* in each variable must be known for all variables.
- Pivot-point models are a simplified form of the logit mode-choice model. Pivot-point models "pivot" off the baseline mode share, based on the *change* in value for certain variables of interest (e.g., transportation LOS).

It is not necessary to know the baseline levels of any other variables, since these baseline levels are reflected in the starting mode share. It is also not necessary to know levels of other variables, such as demographic characteristics, that are assumed not to change.

Standard logit mode-choice models, as applied in regional travel models, can be used to test a broader variety of impacts than pivot-point models. However, since they are integrated with the full regional travel model, they can only be used in conjunction with the entire set of data and modeling processes incorporated in the model. Regional travel models are widely used by MPOs to test the impacts of changes in automobile and transit levels of service, population, employment, demographics, and other variables such as the pedestrian environment. Pivot-point models are based on the same behavioral information (coefficients) and modeling methodology used in regional travel models, yet they apply this methodology in a simplified approach that can be used in stand-alone analysis.

The TDM Evaluation Model, developed by Comsis Corporation in 1993 and sponsored by Federal Highway Administration, uses the same pivot-point methodology as described in this memorandum and the COMMUTER Model User Guide, with the following exception. The TDM Evaluation Model applies the coefficients to zone-to-zone trip activity data (trip tables generated by regional models are input directly into the TDM Evaluation Model); in other words, coefficients are applied separately to trip characteristics and LOS changes between each pair of origin and destination zones. The COMMUTER Model, in contrast, applies the coefficients to a single set of trip activity data, whether it is aggregate metropolitan area data or individual employer data.

The coefficients used in the TDM Evaluation Model and the COMMUTER Model are also very similar. Composite coefficients used in the TDM Evaluation Model were derived from MPO area travel demand models, and average COMMUTER Model coefficients for small, medium, and large size metropolitan areas were also developed from MPO area travel demand models. The primary difference in the coefficient values is that those in the COMMUTER Model are based on more, recent data.

## Review of Coefficient Values

Review - The coefficient values used in the COMMUTER Model are defined as follows:

- In-vehicle travel time (in minutes) for transit modes.*

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* The COMMUTER model was not designed to assess impacts from large changes in the transportation system. As a result, it assumes that in-vehicle travel time remains constant for auto modes (drive alone, carpool, and vanpool) and only allows in-vehicle travel time changes to be applied to transit. Transportation system changes that produce measurable impacts on in-

- Out-of-vehicle travel time (in minutes) is divided into walk and wait parameters. The walk coefficient is used for both auto and transit modes, and the wait coefficient is exclusive to transit modes.

- Cost (in cents) is separated by auto (parking costs) and transit (fare). Auto operating costs were also considered, but are typically the same as transit-fare coefficients.

These parameters are typically established in units of minutes and cents for inclusion into travel demand models and are set to match these units in the COMMUTER Model for consistency. Since there is no guarantee that these units would match an individual city's travel demand forecasting model coefficient units, this should be checked prior to use of the COMMUTER Model. Recognizing that the typical units for cost change inputs and outputs in travel demand forecasting models are dollars, the COMMUTER Model internally applies a cents-to-dollars conversion factor to the cost-related coefficients that are typically reported in cents when combining cost coefficients with cost inputs in dollars. If the user supplies their own local coefficients (instead of using the model's city-specific or area size defaults), the time-related coefficients must be entered in units of minutes and the cost coefficients must be in cents.

All coefficients identified above are expected to be negative, to represent the fact that as the value of the parameter (time or cost) increases, the probability that a person would choose that mode (auto or transit) decreases. The larger the negative value for a coefficient, the greater its impact on the affected mode. A review of a range of values shows that the coefficient values change from city to city and apparently change over time, and these changes in the coefficients can have significant impacts on the results of modal choices.

Table 1 presents the ranges of values for all cities and shows the average coefficient values by city size and over time. The average values in this table demonstrate some trends that transportation planners rely on, such as the following:

- Walk time is twice as onerous as in-vehicle travel time.

- Wait time is more onerous than walk time.

- Approximately three cents of parking cost is equal to one minute of in-vehicle travel time, which translates to an average rate of only $1.80 per hour.

- Transit fares are less onerous than parking cost.

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vehicle travel time for auto modes cannot be assessed with the COMMUTER model and must be treated with a full "four step" travel demand model.

| Table 1<br>Range of Coefficient Values | | | | | |
|---|---|---|---|---|---|
| **Range of Values** | **In-Vehicle (minutes)** | **Walk Time (minutes)** | **Transit Wait Time (minutes)** | **Auto Parking Cost (cents)** | **Transit Fare** (cents) |
| Minimum | -0.0467 | -0.0931 | -0.1165 | -0.0210 | -0.0210 |
| Maximum | -0.0150 | -0.0219 | -0.0280 | -0.0018 | -0.0008 |
| Overall Average | -0.0258 | -0.0484 | -0.0548 | -0.0083 | -0.0061 |
| **City Size** | | | | | |
| less than 750,000 | -0.0207 | -0.0373 | -0.0563 | -0.0065 | -0.0038 |
| 750,000 to 2,000,000 | -0.0241 | -0.0472 | -0.0468 | -0.0071 | -0.0064 |
| more than 2,000,000 | -0.0281 | -0.0521 | -0.0584 | -0.0094 | -0.0065 |
| **Age of Values** | | | | | |
| Less than 1980 | -0.0300 | -0.0491 | -0.0629 | -0.0110 | -0.0110 |
| 1980 to 1990 | -0.0289 | -0.0562 | -0.0543 | -0.0069 | -0.0046 |
| More than 1990 | -0.0204 | -0.0409 | -0.0505 | -0.0079 | -0.0044 |

The coefficient values by city size show a clear trend toward larger coefficients for larger cities, with the exception of transit wait time for small cities. This anomaly could be due to a small sample size in this category or values that do not change by city size for this variable. The coefficient values over time also show a general trend toward lower coefficient values in later models, but this is generally believed to be reflective of the fact that models with more variables and better explanatory powers would have lower values for these variables.

## Examples

The values of the coefficients can best be described with examples, as shown in Table 2. The first example shows the impacts of improved transit service by itself. The second example shows the impacts of improved transit service combined with an additional charge for parking. These examples present the type of sensitivity analysis that some regional agencies conduct to compare the effects of variables both individually and in combination. The size of the coefficient affects the impact of the variable on the mode share, but only in context with the pivot-point logit model equation. One description of this approach can be found in "Modeling Transport" by J. de D. Ortuzar and L.G.

Willumsen (Wiley Publishers, 1990), page 302.

| **Table 2**<br>**Examples of Sensitivity Testing of Coefficient Values** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Example #1: Reduced Transit Travel Time** | | | | | | | | |
| | Travel Time (min.) | | | | Cost (cents) | | | |
| | Auto in- | Transit | Transit | Transit | Auto | Transit | | |
| Original | 20 | 40 | 10 | 10 | 100 | 150 | | |
| Improved | 20 | 35 | 10 | 10 | 100 | 150 | | |
| Difference | 0 | -5 | 0 | 0 | 0 | 0 | | |
| | | | | | | | New Mode Shares: | |
| Utility | | | | | | | Auto | Transit |
| Small | 0.000 | 0.103 | 0.000 | 0.000 | 0.000 | 0.000 | 89.0% | 11.0% |
| Medium | 0.000 | 0.120 | 0.000 | 0.000 | 0.000 | 0.000 | 88.9% | 11.0% |
| Large | 0.000 | 0.134 | 0.000 | 0.000 | 0.000 | 0.000 | 88.7% | 11.3% |
| **Example #2: Reduced Transit Travel Time + Increased Parking Cost** | | | | | | | | |
| | Travel Time (min.) | | | | Cost (cents) | | | |
| | Auto in- | Transit | Transit | Transit | Auto | Transit | | |
| Original | 20 | 40 | 10 | 10 | 100 | 150 | | |
| Improved | 20 | 35 | 10 | 10 | 150 | 150 | | |
| Difference | 0 | -5 | 0 | 0 | 50 | 0 | | |
| | | | | | | | New Mode Shares: | |
| Utility | | | | | | | Auto | Transit |
| Small | 0.000 | 0.103 | 0.000 | 0.000 | -0.326 | 0.000 | 85.4% | 14.6% |
| Medium | 0.000 | 0.120 | 0.000 | 0.000 | -0.356 | 0.000 | 84.8% | 15.2% |
| Large | 0.000 | 0.134 | 0.000 | 0.000 | -0.468 | 0.000 | 83.1% | 16.9% |

The calculations presented in Table 2 include default coefficients by population size input into the COMMUTER Model, and assume current mode shares of 90% auto and 10% transit. In the first example:

- Level of service (LOS) changes include improved transit service (five minutes faster in-vehicle travel time); and

- Computations indicate an expected increase in transit use from 10% to 11.0%, 11.1%, and 11.3% for small, medium, and large size metropolitan areas, respectively.

In the second example:

- LOS changes include improved transit service (five minutes faster in-vehicle travel time) combined with a parking cost increase from $1.00 to $1.50.

- The computations show an expected increase in transit use from 10% to 14.6%, 15.2%, and 16.9% for small, medium, and large size metropolitan areas, respectively. The greater shift to transit in Example #2 illustrates the combined effect of the service changes.

Each coefficient, when multiplied by the corresponding change in LOS, indicates a change in "utility" for the mode. Utility is a relative measure of attractiveness; essentially, the coefficients are converting changes in different units (minutes, cents, etc.) into similar terms so they can be directly compared. Larger coefficient values on variables with the same units indicate a higher value on that variable. For example, as shown in the Table 1 coefficients, out-of-vehicle travel time is valued more highly than in-vehicle travel time (people dislike to wait). The utility changes from each LOS component are then combined to determine an overall change in mode share using the logit model equation.

The underlying computations are shown below for Example #1 with a small metropolitan area.

Utility change: $\Delta U$ = Coefficient × Change in LOS

Transit utility change: $\Delta U_{Trans} = (-0.207) * (-5) = 0.103$

New transit mode share:

$$P'_{Trans} = \frac{P_{Trans} \times e^{\Delta U_{Trans}}}{(P_{Auto} \times e^{\Delta U_{Auto}}) + (P_{Trans} \times e^{\Delta U_{Trans}})} = \frac{0.10 \times e^{0.103}}{(0.90 \times e^{0}) + (0.10 \times e^{0.103})} = 11.0\%$$

where

$P'_{Trans}$ = new transit mode share
$P_{Trans}$ = base (existing) transit mode share
$P_{Auto}$ = base auto mode share
$\Delta U_{Trans}$ = transit utility change
$\Delta U_{Auto}$ = auto utility change

## Documentation of Sources

The sources for the model coefficients used in the COMMUTER Model are identified in this section.  The majority of these sources were also identified and presented under EPA Work Assignment 98 0-06.*

Document #1: - *I-95/I-595 Multimodal Transportation Master Plan – Revised Travel Forecasting and Analysis Methodology Report*, Cambridge Systematics, Inc. and Reynolds, Smith, and Hills, Inc, prepared for Florida Department of Transportation, District 4, 1998.

This document provided travel model coefficients for various cities including the following:

- **Composite Model** (made up of coefficients from 1960 to 1984 - Schultz, Gordon.  Memorandum to Seattle Metro files, March 5, 1991);

- **Atlanta Model** (from 1989 – two sources: (1) Cambridge Systematics and Barton-Aschman Associates, *Short Term Travel Model Improvements*, prepared for the USDOT Travel Model Improvement Program, October 1994; and (2) Metropolitan Atlanta Rapid Transit Authority,. *North Line Corridor Alternatives Analysis/DEIS Environmental Impact Statement, Atlanta, Georgia, Deliverable 10: Methodology for Analysis of Service and Patronage Impacts*, prepared for the Urban Mass Transportation Administration, April 1989);

- **Detroit Model** (from 1984 - Cambridge Systematics, Inc., *SEMCOG Travel Demand Model Refinement Project, Final Report*, July 1992);

- **Los Angeles Model** (from 1996 - Cambridge Systematics, Inc., *SCAG Regional Mode Choice Model Development Project, Final Report,* October 28, 1996);

- **Milwaukee Model** (from 1991 - Southeastern Wisconsin Regional Planning Commission, *Travel Simulation Models for the Milwaukee East-West Corridor Transit Study*, May 1993);
- **Portland Model** (from 1994 - Metro, *The Phase III Travel Demand Forecasting Model: A Summary of Inputs, Algorithms, and Coefficients*, June 1, 1994);

- **Philadelphia Model** (from 1996—preliminary - Cambridge Systematics,

* S. Decker and R. Dulla, "Technical Memorandum #1:  Identification of Literature for Task 2, and the Synthesis and Analysis of Criteria for Task 3,"  memorandum to John Hall, Environmental Protection Agency, June 30, 1998.

Inc., *Task 3 Report: Nested Mode Choice Model*, prepared for the Delaware Valley Regional Planning Commission, March 1998);

- **Sacramento Model** (from 1994 - DKS Associates, *Model Development and User Reference Report*, prepared for the Sacramento Area Council of Governments, October 1994); and

- **Tucson Model** (from 1994 - JHK and Associates and Cambridge Systematics, Inc., *PAG Travel Demand Study*, submitted to Pima Association of Governments, March 1994).

Miami model coefficients were also identified in this document for in-vehicle travel times.

Document #2 - *Short-Term Travel Model Improvements*, Cambridge Systematics, Inc., with Barton Aschman Associates, prepared for U.S. Department of Transportation, Federal Highway Administration, Federal Transit Administration, Office of the Secretary, and U.S. Environmental Protection Agency, October 1994.

This document provided travel model coefficients for the following cities:

- New Orleans (from 1960);
- Minneapolis (from 1970);
- Cincinnati (from 1978);
- Los Angeles (from 1975);
- San Francisco (from 1980);
- San Juan, Puerto Rico (from 1984);
- Seattle (From 1977);
- St. Louis (from 1984); and
- Washington, DC (from 1980 and 1984).

Document #3 - *Travel Demand Forecasting Processes Used by Ten Large Metropolitan Planning Organizations*, Institute of Transportation Engineers, prepared by ITE Technical Council Committee 6Y-53, February 1994.

This document was used by Cambridge Systematics to identify additional travel model coefficients for use in the COMMUTER Model. Metropolitan area travel model coefficients identified from this source included the following:

- Detroit (from 1965);
- St. Louis (from 1965);
- Washington, DC (from 1980);
- Pittsburgh (from 1978);
- Dallas (from 1984);
- Denver (from 1985); and

- Atlanta (no year defined).

Document #4 - *TDM Evaluation Model User's Guide*, Comsis Corporation, prepared for Federal Highway Administration & Federal Transit Administration, 1993.

This document provided travel model coefficients for various cities including the following sources (by city):

- Honolulu (from 1982);
- Cobb County, Georgia (from 1990);
- I-80 New Jersey (from 1990);
- Houston (from 1994);
- Somerset, New Jersey (from 1989);
- Los Angeles (from 1982);
- Miami (from 1982);
- Minneapolis (from 1991 and 1975);
- New Orleans (from 1980);
- Phoenix (from 1990);
- San Juan, Puerto Rico (from 1982);
- Seattle (from 1991 and 1978);
- St. Louis (from 1982); and
- Washington, DC (from 1985).

Other Documents/Sources - Many of the coefficients were obtained directly from the consultant travel demand modelers responsible for regional model estimation. These metropolitan areas included the most recent model updates conducted in the following:

- Santa Cruz, California (from 1990);
- Cleveland (from 1994);
- Phoenix (from 1997);
- San Diego (year undefined); and
- Reno (from 1991).

Others were obtained directly from the travel demand model documentation reports prepared for each metropolitan area including the following:

- San Francisco (from 1990);
- San Juan (from 1990);
- Albuquerque (from 1992); and
- Phoenix (from 1997).

Other sites were obtained from NCHRP 187 including the following:

- Chicago (from 1990);
- Salt Lake City (year undefined); and
- Portland (from 1992).

## Summary

The COMMUTER Model will be a more powerful tool to the user if the impacts of the coefficients are understood. The best means to achieve this understanding is to use sensitivity testing similar to that presented in this discussion. This will serve to indicate the general impacts to changes in cost or time variables as well as to identify that the model and data are being applied correctly.